

ES 691

Mathematics for Machine Learning

with

Dr. Naveed R. Butt

@

GIKI - FES

- In the last lecture we saw the Magic of Learning
 - In organisms.

- We now look at the “Magic” of Learning
 - In algorithms & objects...

The Magic of Learning! (In Machines...)

- How do you think machines learn?

The Magic of Learning! (In Machines...)

- How do you think machines learn?
 - Mostly *algorithmically*!

Why Did the Robot Cross the Road?



*At higher-level,
algorithms mostly
logical:*

*If bike CROSS NORMAL
If motorbike CROSS
QUICKLY*

Why Did the Robot Cross the Road?



*At higher-level,
algorithms mostly
logical:*

*If bike CROSS NORMAL
If motorbike CROSS
QUICKLY*

*At deeper level,
algorithms mostly
mathematical:*

*Distinguish between bike
and motorbike from
image frames.*

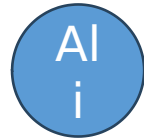
But how can algorithms teach a machine?

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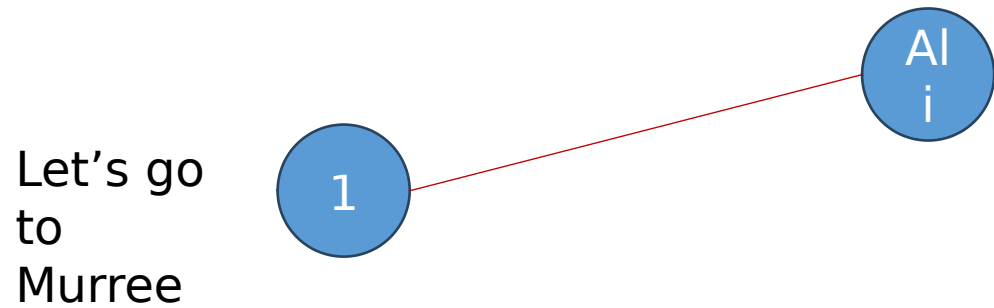
*.. And like neurons/organisms, can we achieve something **COMPLEX** using **REPETITIONS** of rather **SIMPLE UNITS** with rather **SIMPLE RULES**?*

To Murree or Not to Murree...

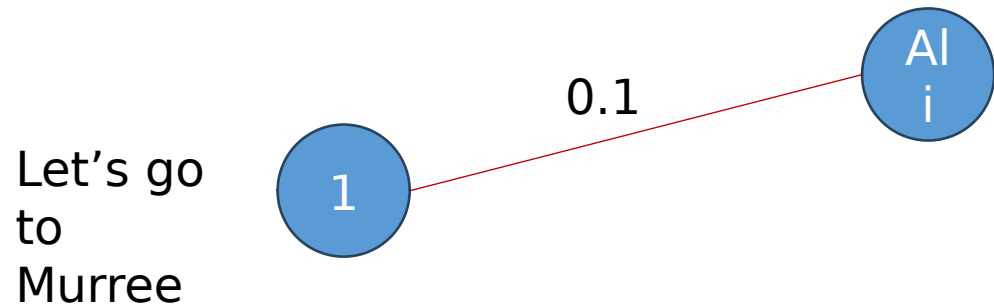
To Murree or Not to Murree...



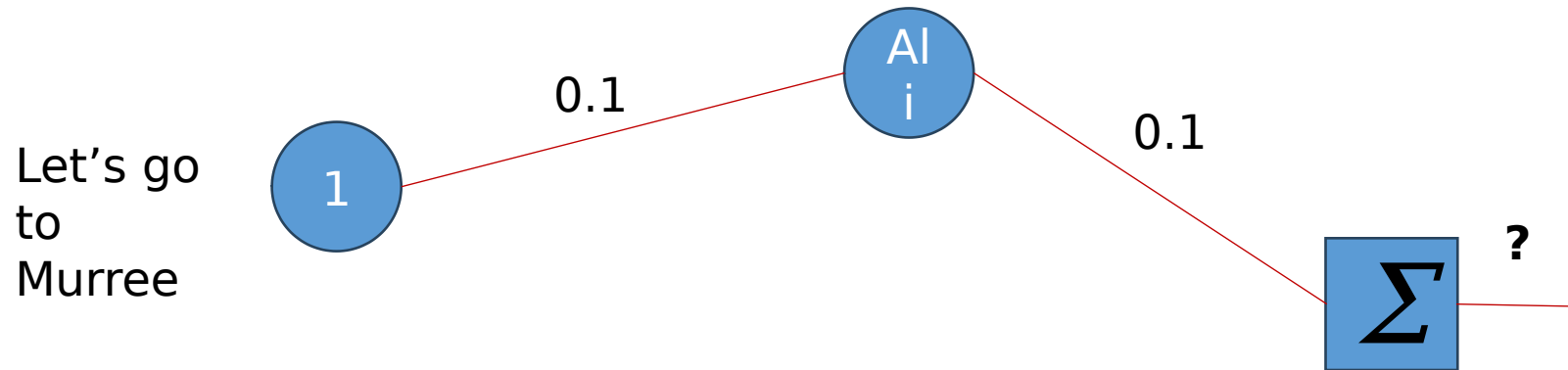
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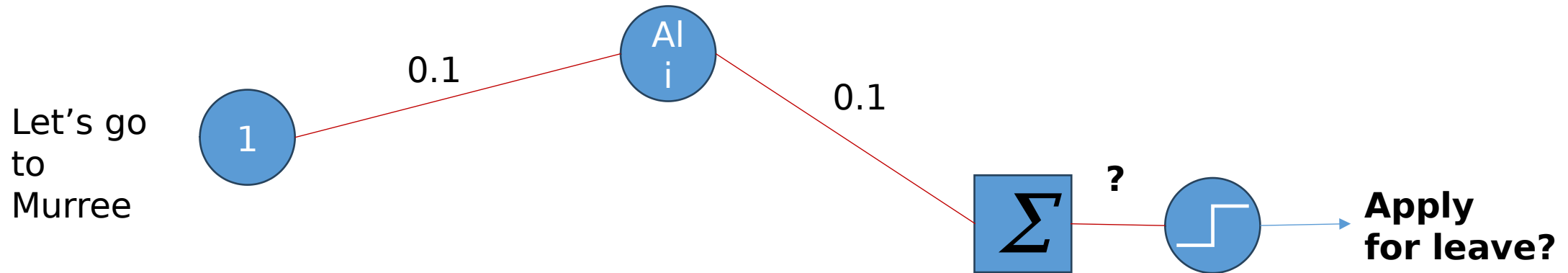
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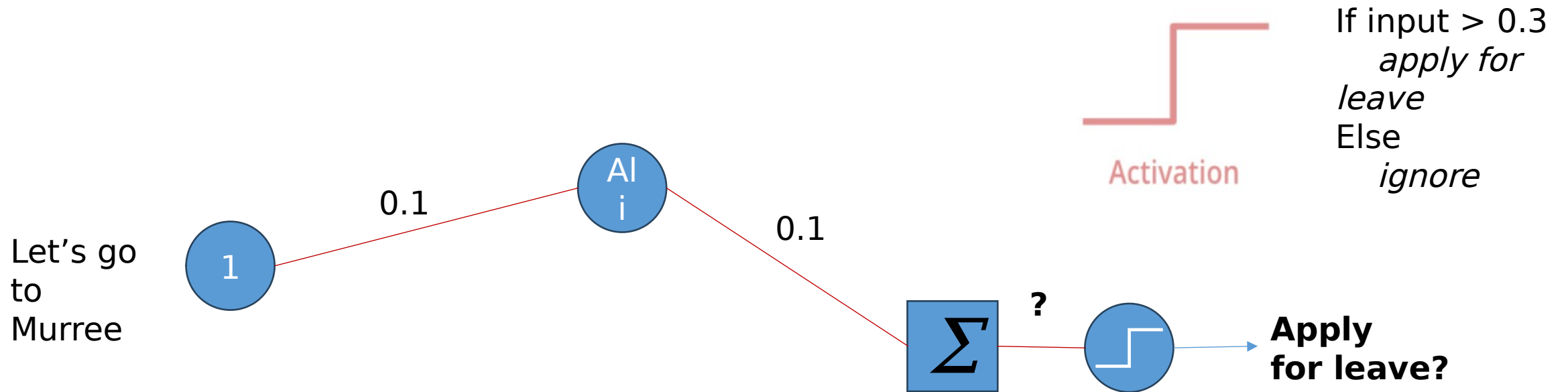
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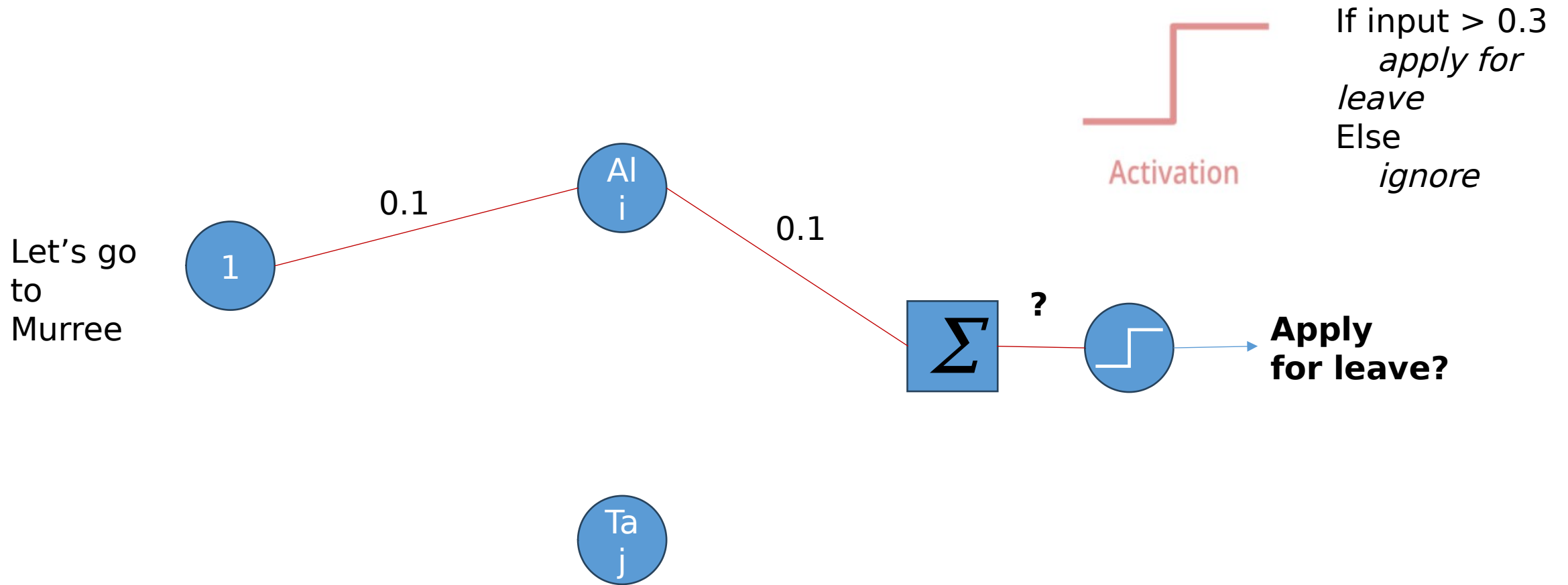
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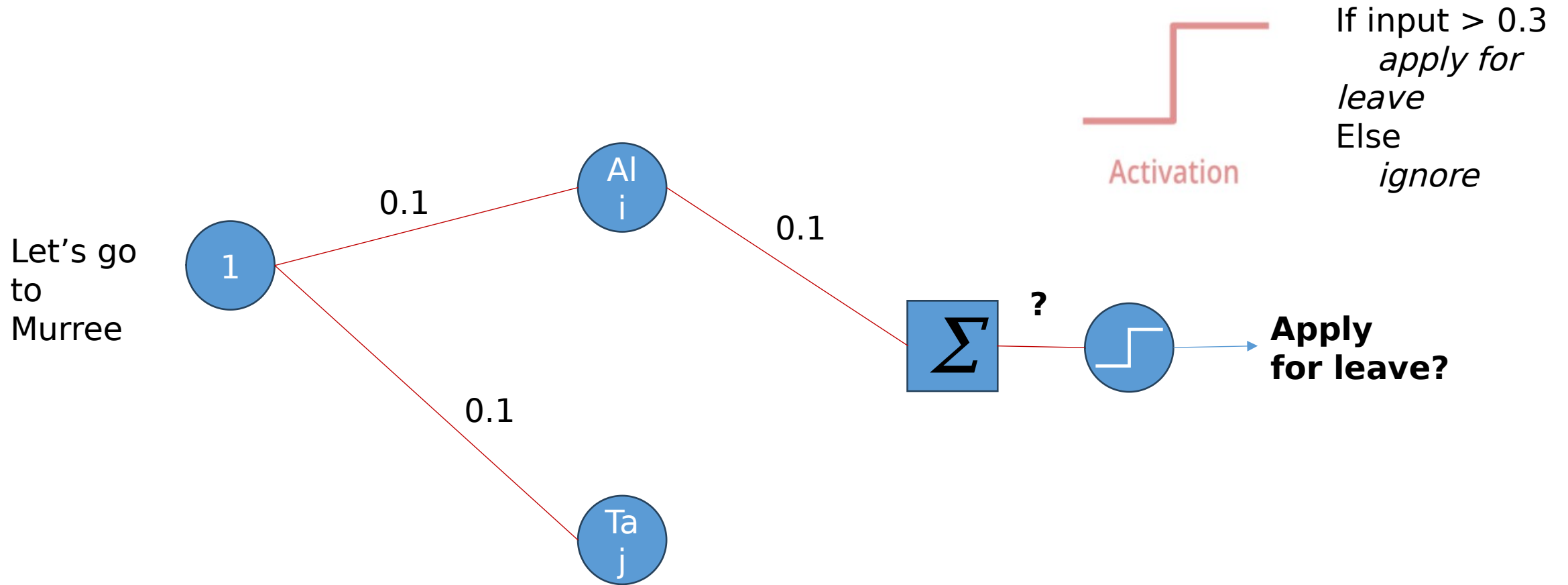
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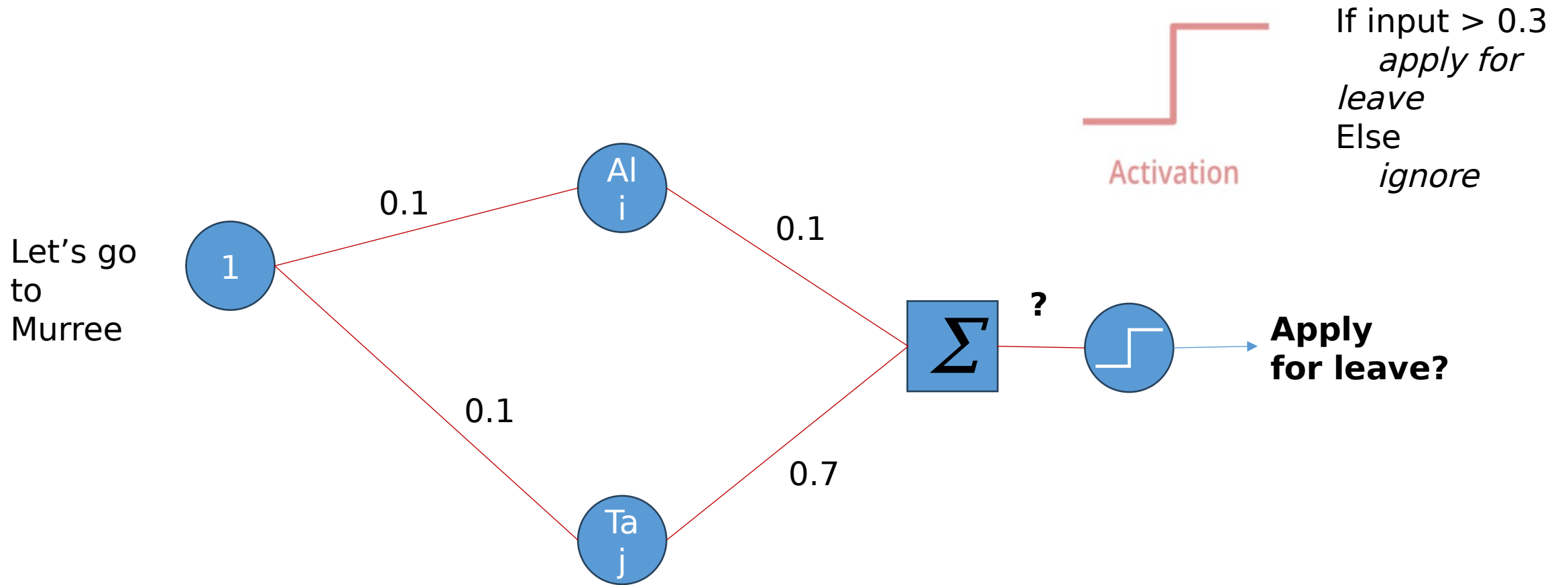
To Murree or Not to Murree...



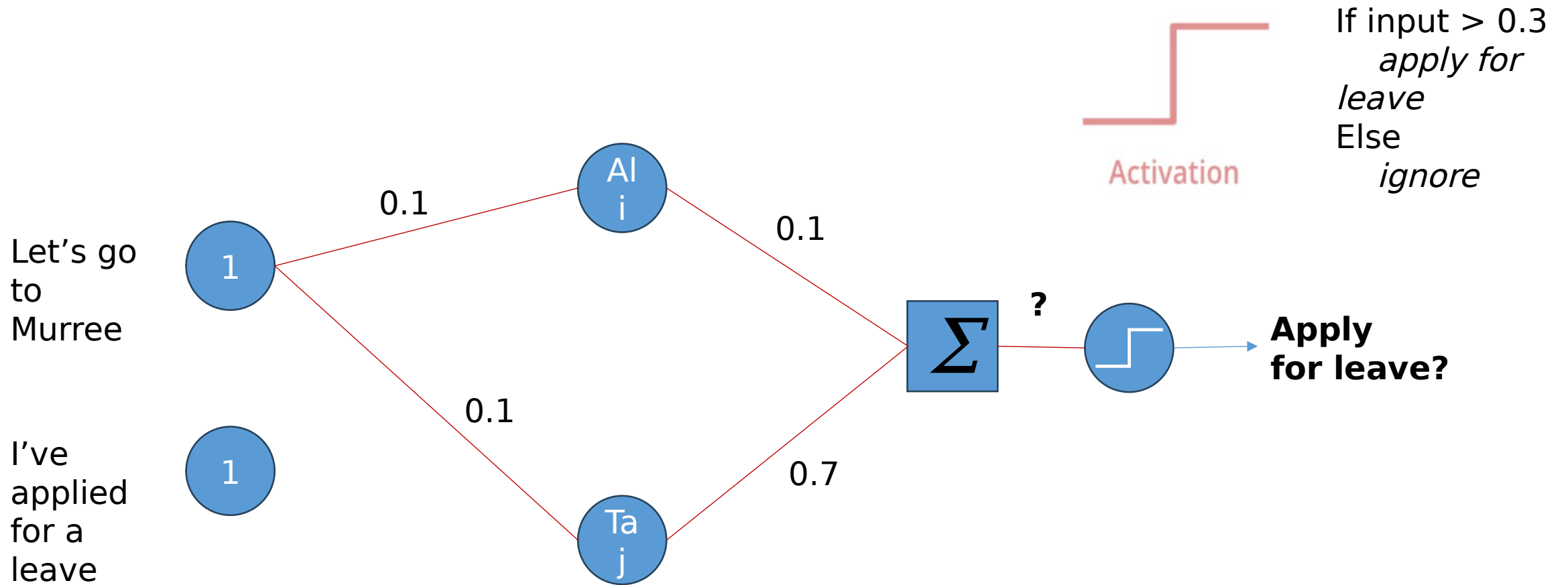
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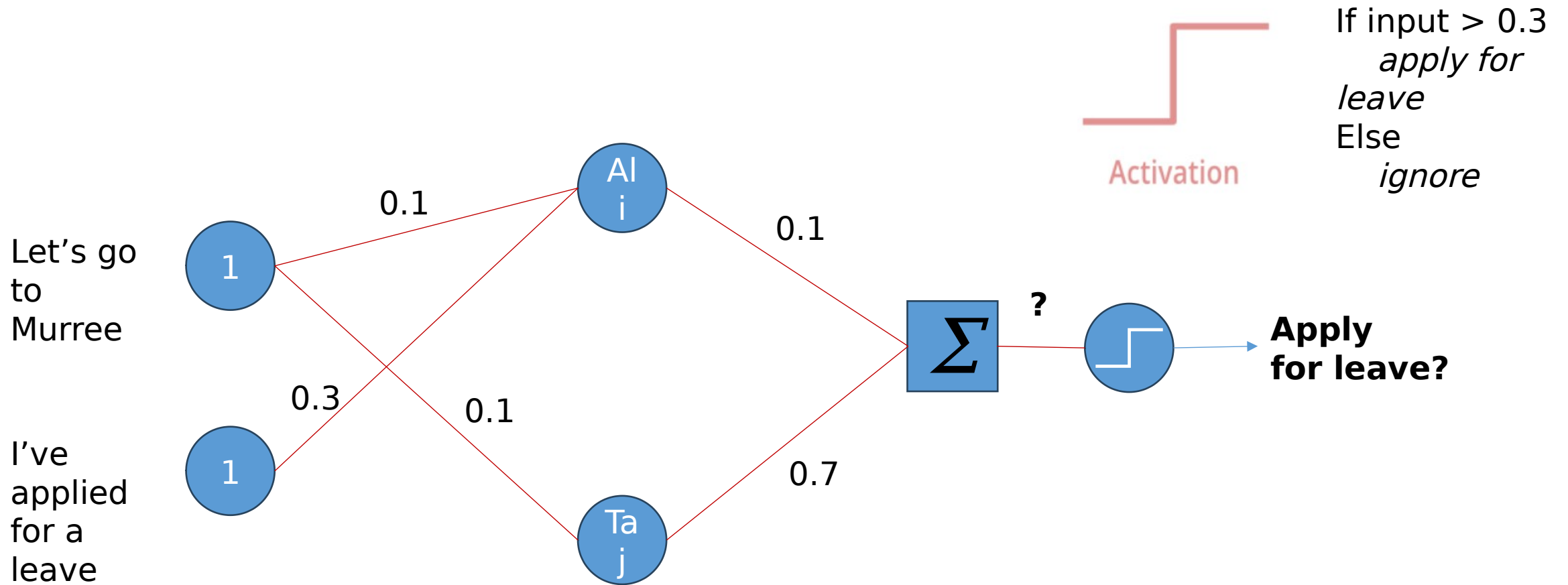
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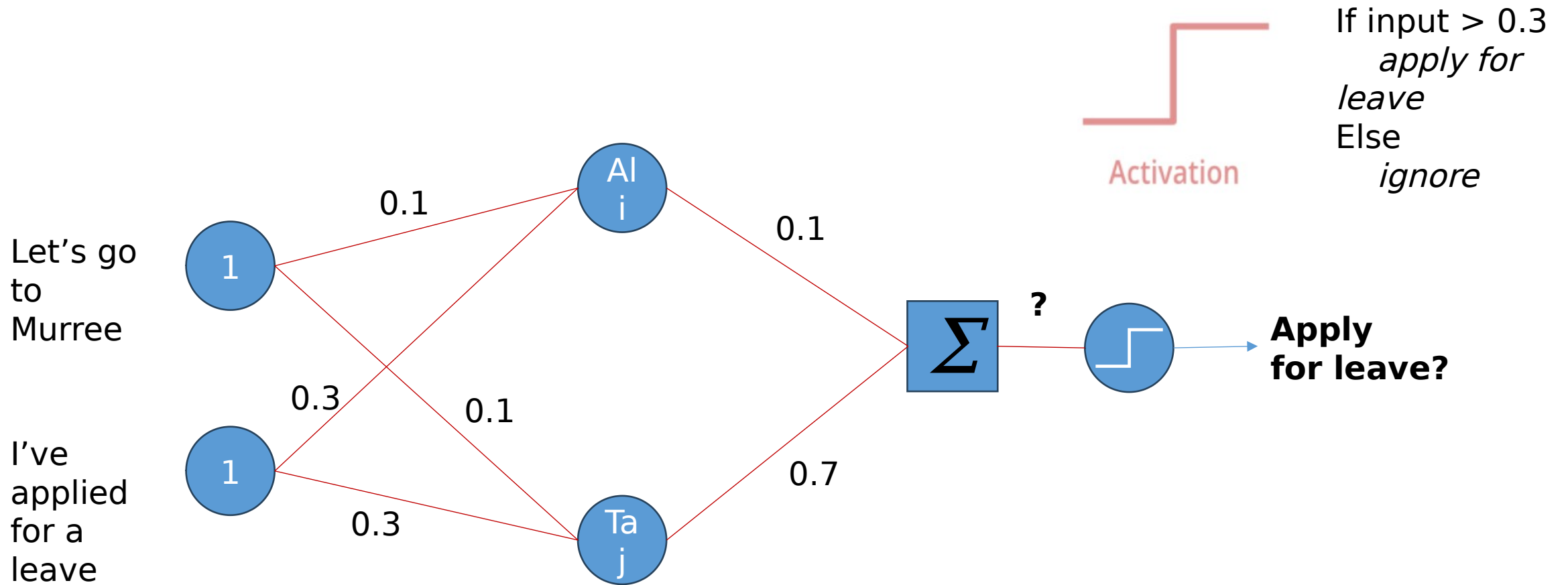
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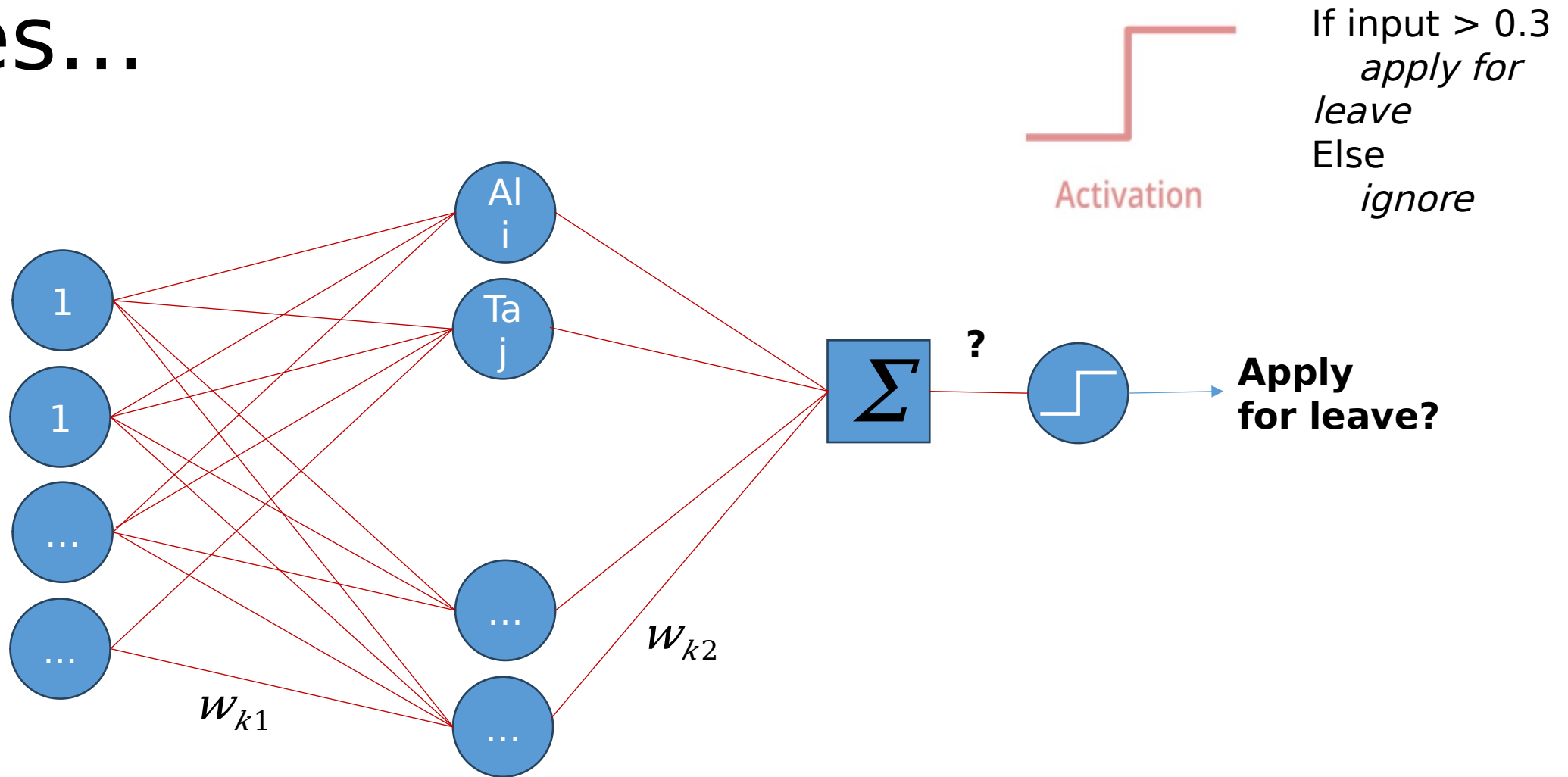


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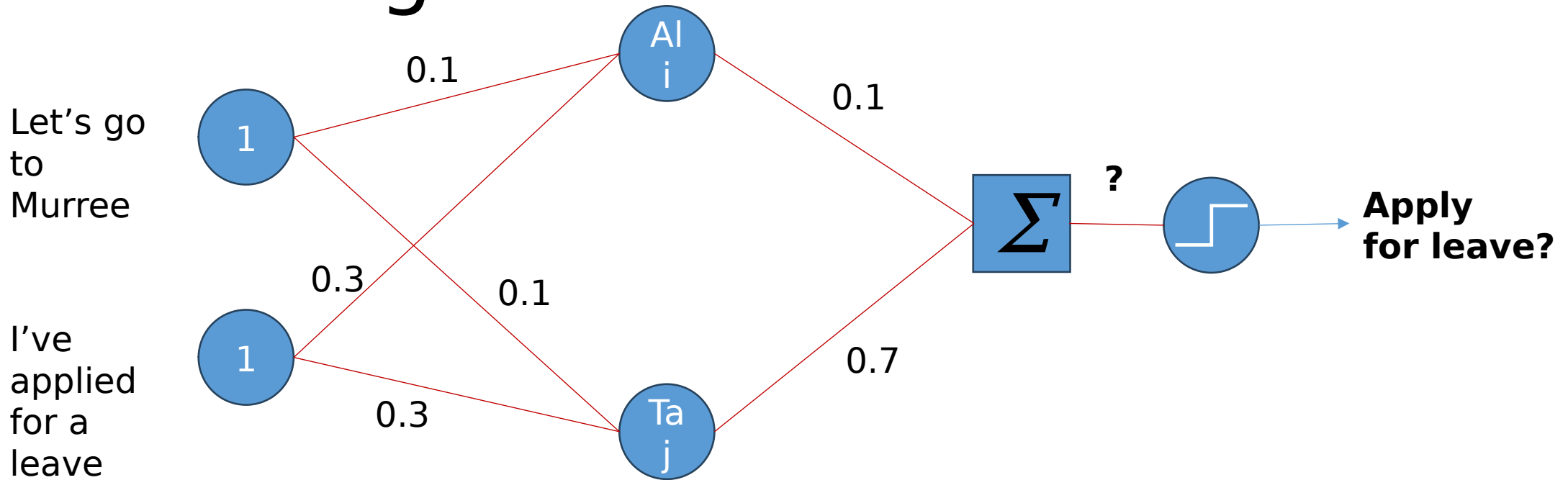


Of course, you could replicate these simple components and simple rules...

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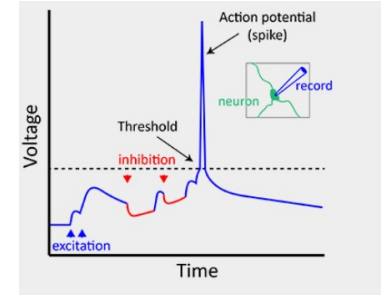
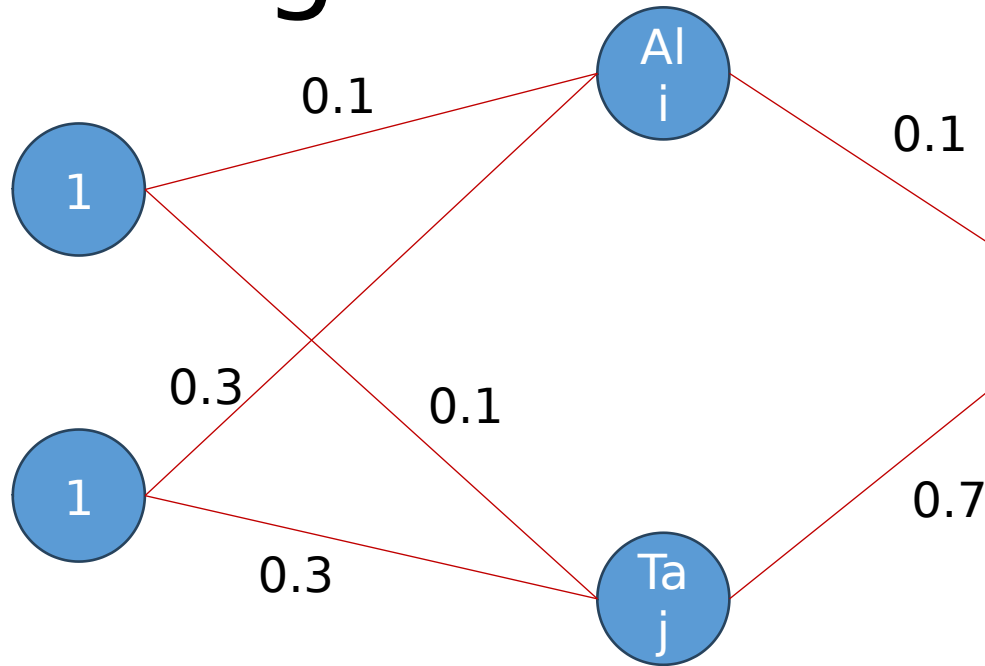
Btw, does this remind you of something?



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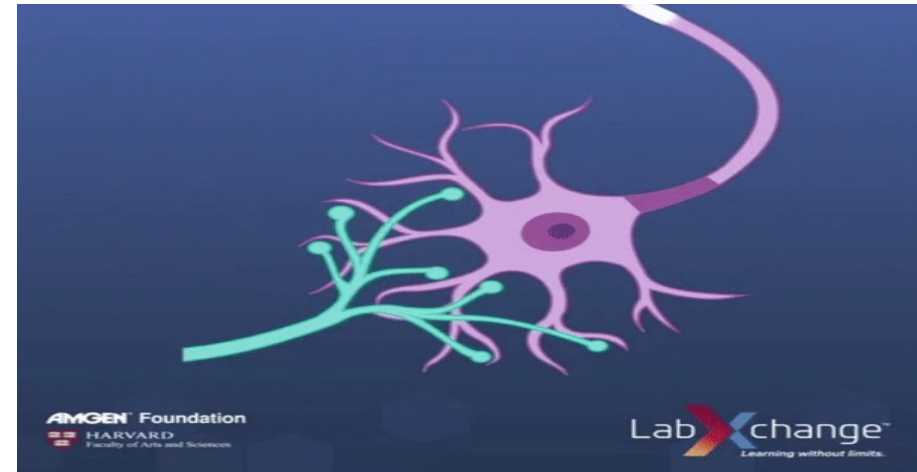
Let's go to Murree

I've applied for a leave



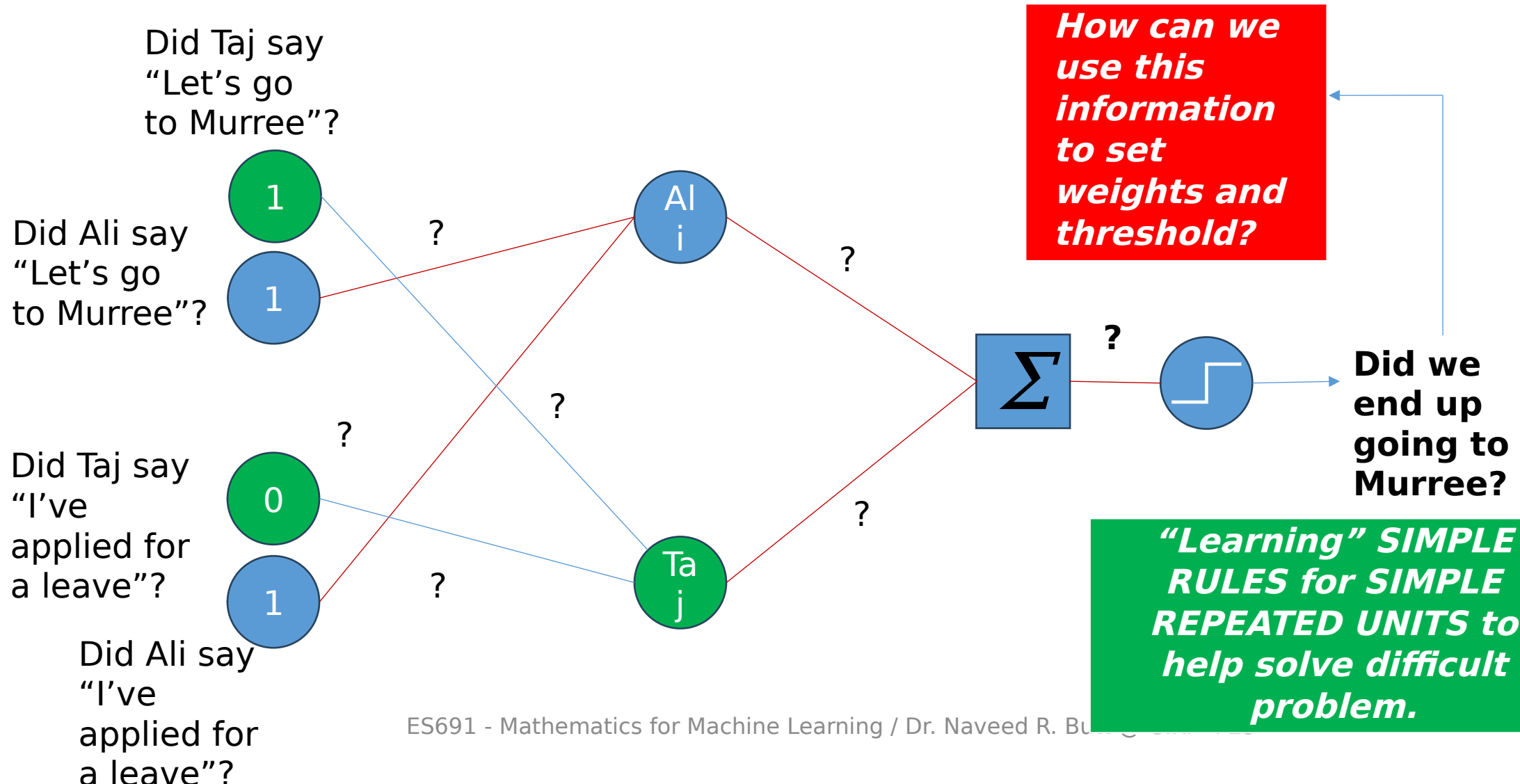
Apply for leave?

Breaking a problem into simpler units and rules!

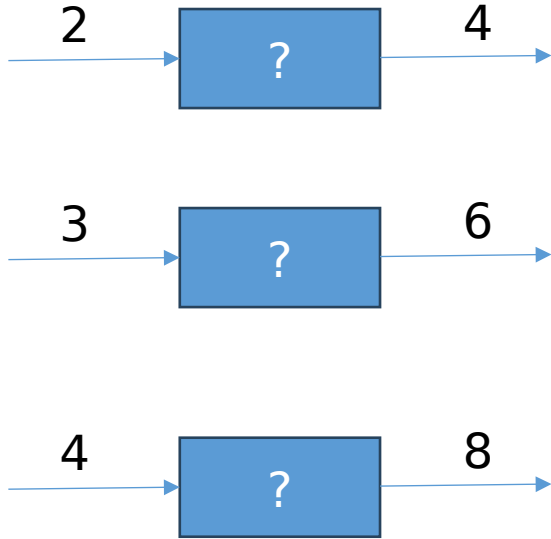


You may also want to do it in
reverse...

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“Learning” rules from input-output or history...



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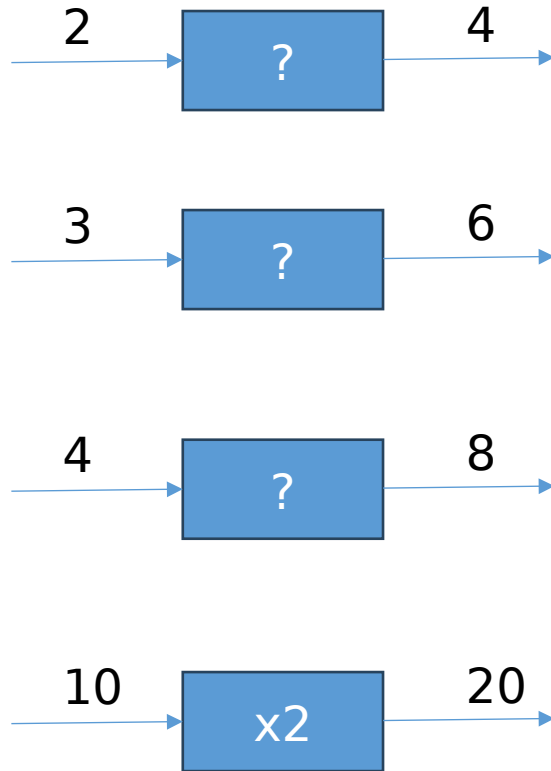


“Learning” rules from input-output or history...

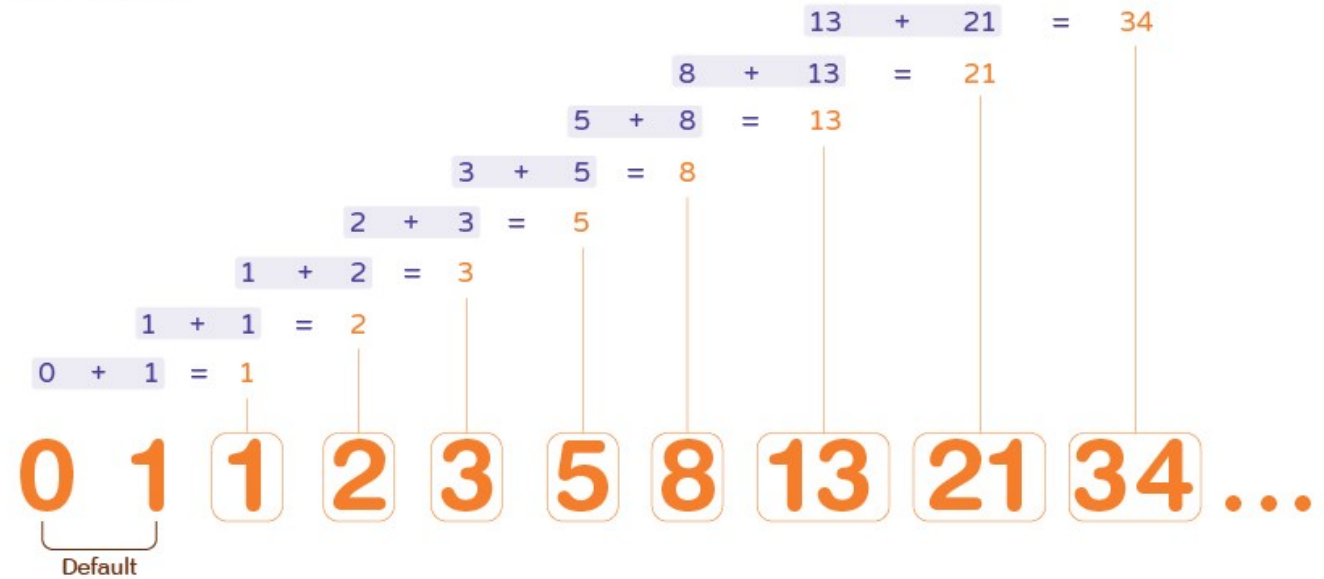


0 1 1 2 3 5 8 13 21 34 ...

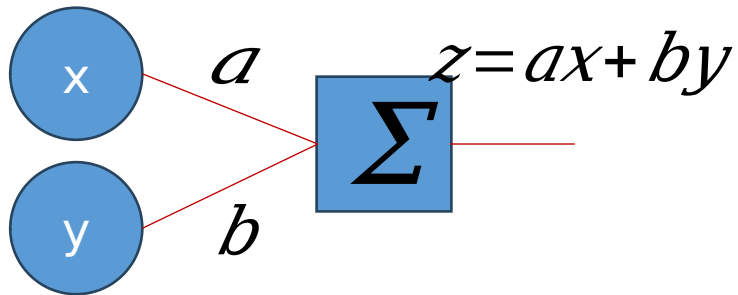
“Learning” rules from input-output or history...



Numbers



Learning Iteratively vs. Direct Solution

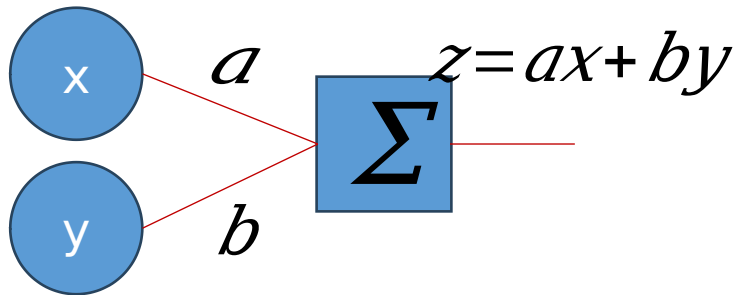


Showing that iterative learning with simple rules can work!

Suppose you have to learn and iteratively with following rules

- We initialize
- After each iteration, either w or b can go up or down by 1, but not both.
- Update criteria is to minimize E , where $E = \frac{1}{2} \sum (d_i - z_i)^2$, d_i = desired value, and z_i = obtained value.

Learning Iteratively vs. Direct Solution



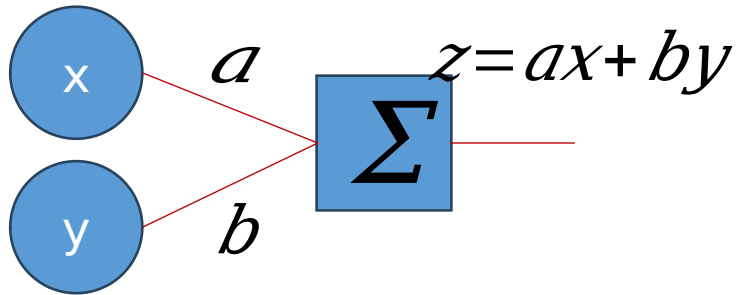
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Given	Current	Obtain ed		New

Learning Iteratively vs. Direct Solution



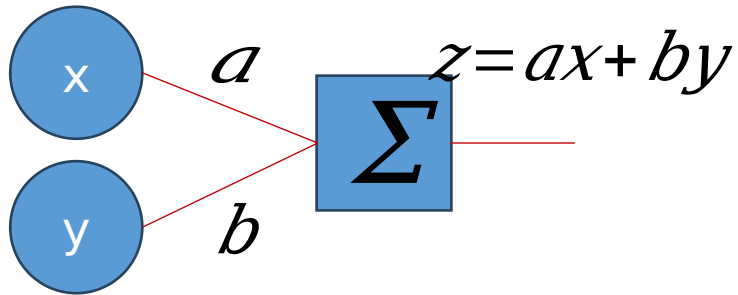
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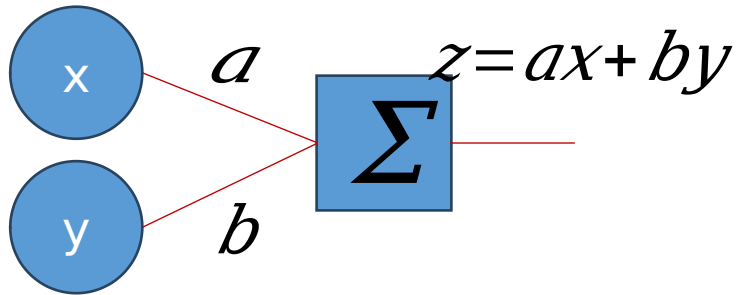
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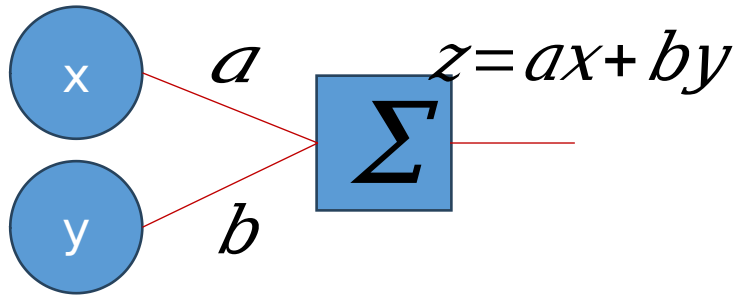
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Given	Current	Obtain ed		New
				No update needed as

Learning Iteratively vs. Direct Solution



Can we do something smarter about this?

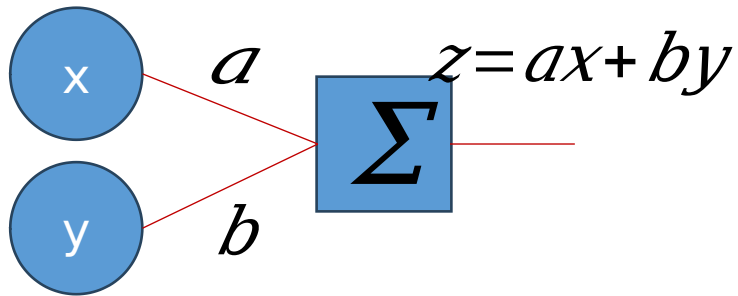
Showing that iterative learning with simple rules can work!

Suppose you have to learn and iteratively with following rules

- We initialize
- After each iteration, either w can go up or down by 1, but not both.
- Update criteria is to minimize E , where w_d = desired value, and w_o = obtained value.

Given	Current	Obtained		New
				No update needed as

Learning Iteratively vs. Direct Solution

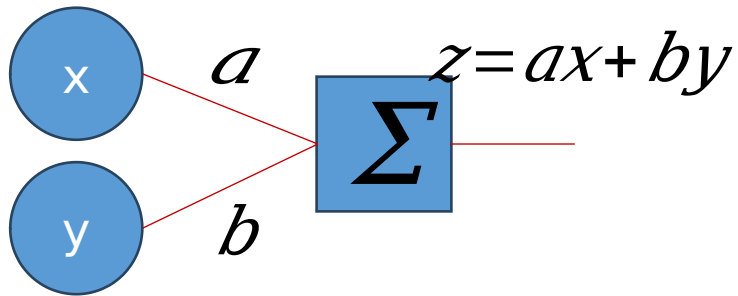


*But we could have
done this directly as
well...*

Yes, but remember

- We are showing that it is possible iteratively with simple rules
- As the problem becomes bigger and more intractable, direct solutions will be elusive, while the simple iterative rules could still work with lots of nodes with simple rules.
- In fact, in many real world problems we may not even be sure how to *define* parameters of a problem (but such repeated simple structures may come in handy).

Learning Iteratively vs. Direct Solution



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- In fact, in many real world problems we may not even be sure how to *define* parameters of a problem (but such repeated simple structures may come in handy).

**Is This a
Good
Poem for
the
Course?**

*In the world of math, we find our way,
To teach machines how to learn and play.
With numbers and patterns, we pave the
road,
For algorithms to decipher and decode.*

*Machine learning relies on math's
foundation,
To make sense of data and find
information.
From linear equations to complex graphs,
We use every tool, every formula we have*

*Statistics and probabilities guide the way,
In predicting outcomes and making data
sway.
With calculus and algebra, we analyze
trends,
To make machines smarter, our knowledge
extends.*

*So embrace the power of math in machine
learning.*

OK, but do these kind of learning approaches actually lead to something amazing?

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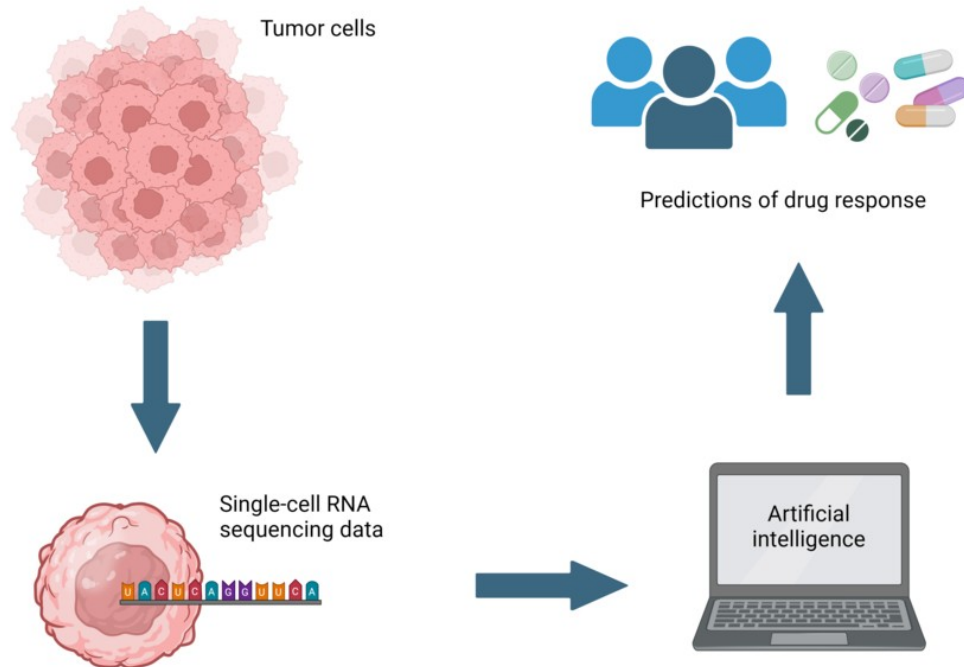
(Really?)

June 25, 2024

AI tool predicts response to cancer therapy

At a Glance

- Scientists developed an AI tool that uses routine clinical data to identify cancer patients most likely to respond to immunotherapy drugs called checkpoint inhibitors.
- The approach could help guide personalized cancer treatments for patients.



Personalized Medicine



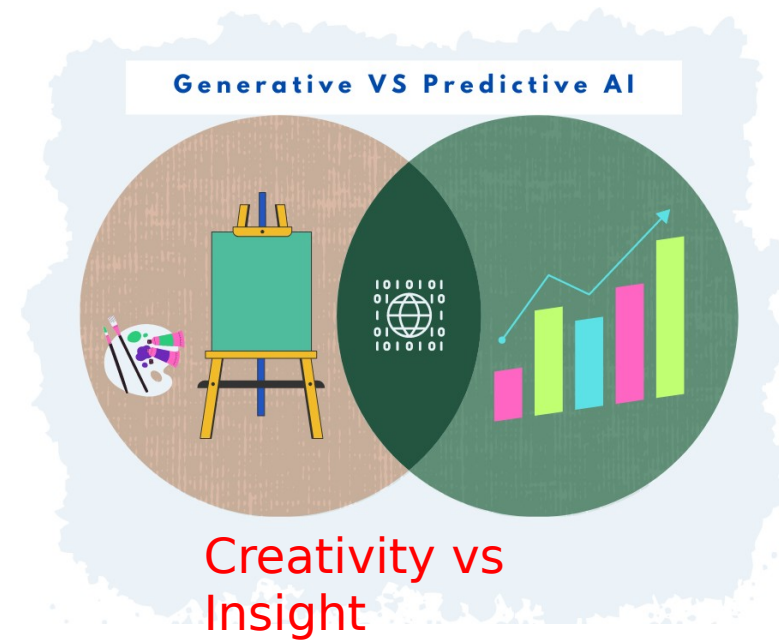
Dr.
**BILAL
MALIK**

PRINCIPAL SCIENTIST
- CLINICAL IMAGING
GENENTECH

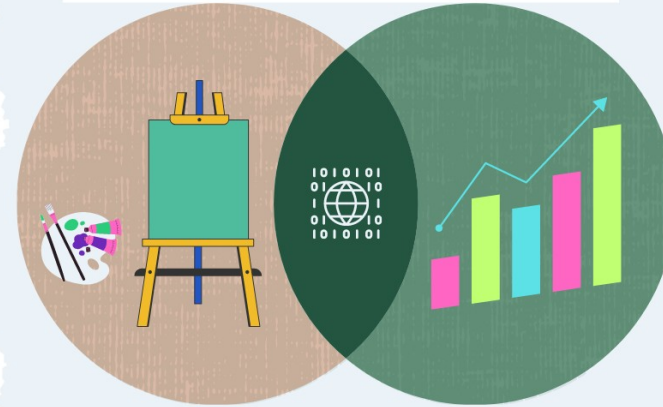
ENGINEERING SCIENCES '02

DEVELOPING NEW WAYS FOR

**EARLY
DETECTION
OF
CANCER**



Generative VS Predictive AI



Creativity vs Insight



Ibné Muneeb

August 17 at 11:07 PM · 🌐

Asked ChatGPT to explain one of my ghazal's. Quite impressive response (English translation of the verses is also by ChatGPT)

Certainly! Here's an explanation of the poem by **Ibne Muneeb**:

Explanation of the Poem

1. **دلوں میں فاصلے ہوں تو**
سفر دشوار ہوتا ہے
اماں دیتا نہ ہو جو گھر
وہ گھر بیکار ہوتا ہے

When there are distances in hearts,
Travel becomes arduous.
A home that does not offer shelter,
Is a home that is of no use.

- **Explanation**: The poet starts by expressing that emotional distance between people makes any journey or relationship difficult. A home that does not provide warmth and safety is rendered useless. This highlights the importance of emotional connection and genuine support in relationships.

4. **انوکھے ساز بجاتے ہیں**
جگر جب تار ہوتا ہے
کوئی تو درد کا قصہ
پس اشعار ہوتا ہے!

Unique melodies play
When the liver becomes a string.
Any tale of pain
Is hidden behind verses.

- **Explanation**: The poet uses a metaphor of the liver (often associated with deep emotions in classical literature) being used as a musical string to describe how deep emotions create unique and profound expressions. Stories of pain are often concealed within poetic verses, illustrating how art can express what is felt internally.

Urdu

↔

English

×

انوکھے ساز بجاتے ہیں
جگر جب تار ہوتا ہے
کوئی تو درد کا قصہ
پس اشعار ہوتا ہے!

▶

Strange instruments
play
When the liver is
wired
A story of pain
So there is poetry!

📄

▶

🌐

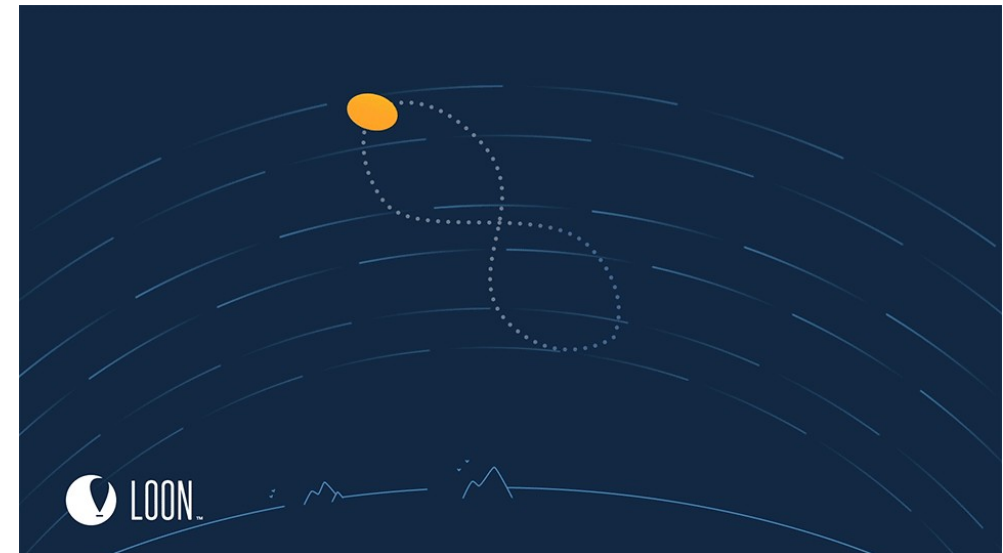
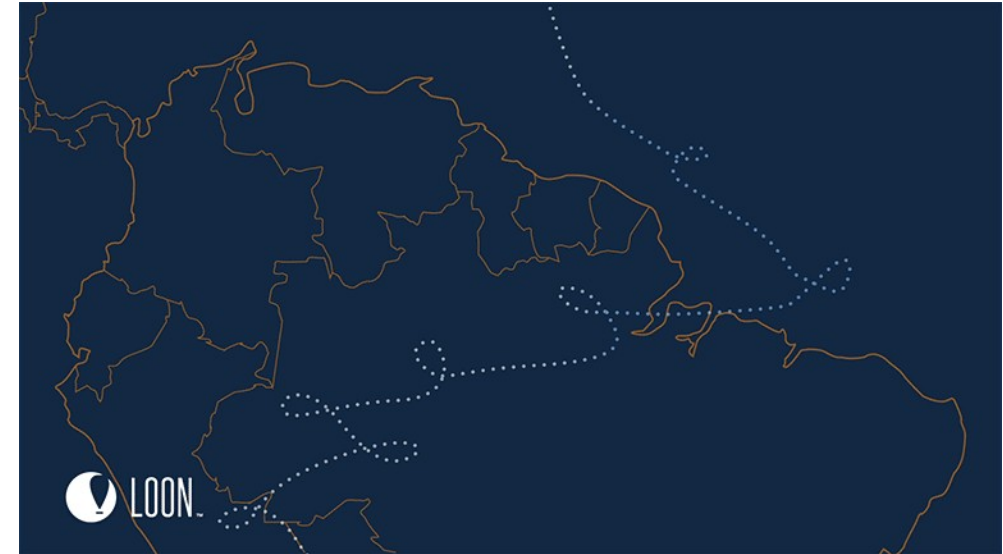
[Open in Google Translate](#) • [Feedback](#)

**4. انوکھے ساز بجاتے ہیں
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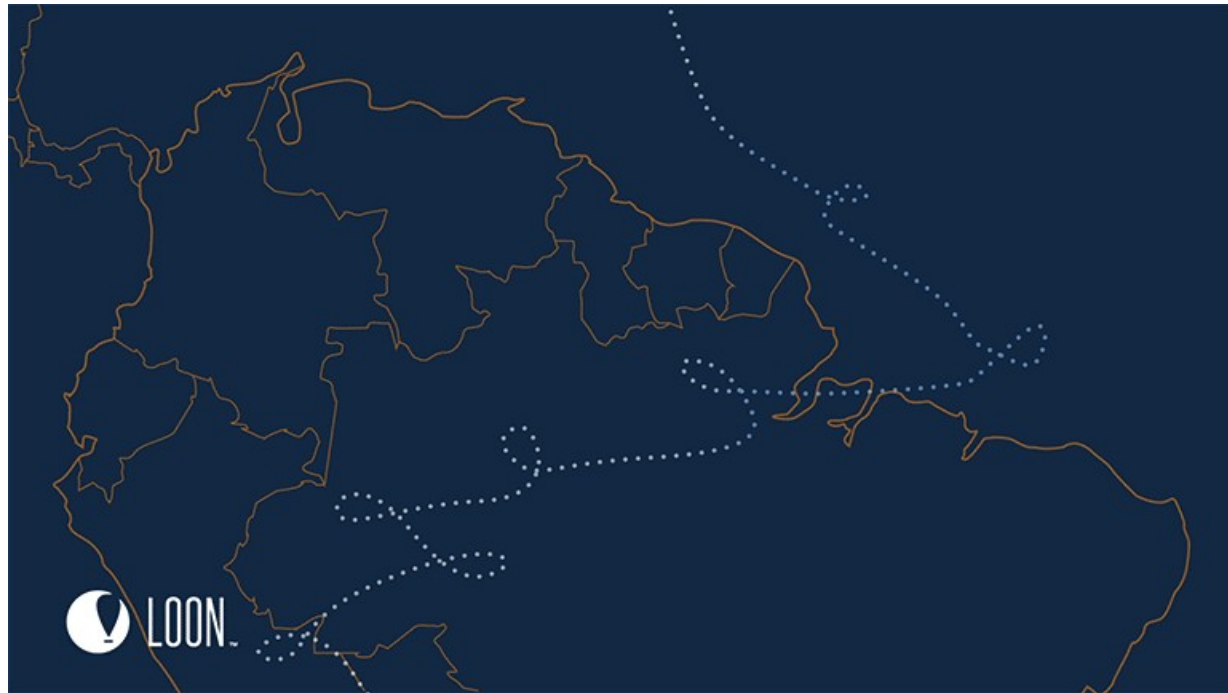
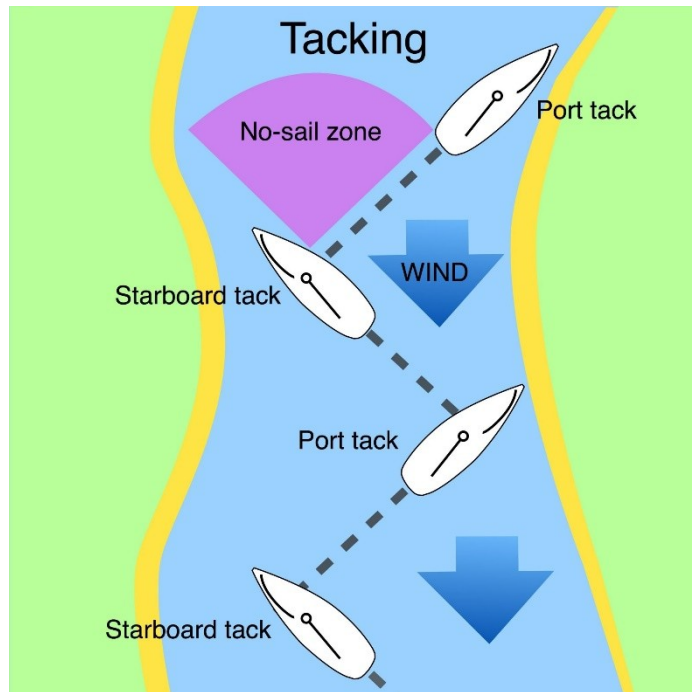
How Google's balloons surprised their creator



It was only later that they realised what was happening. Unexpectedly, the artificial intelligence (AI) on board the balloon had learned to recreate an ancient sailing technique first developed by humans centuries, if not **thousands of years**, ago.

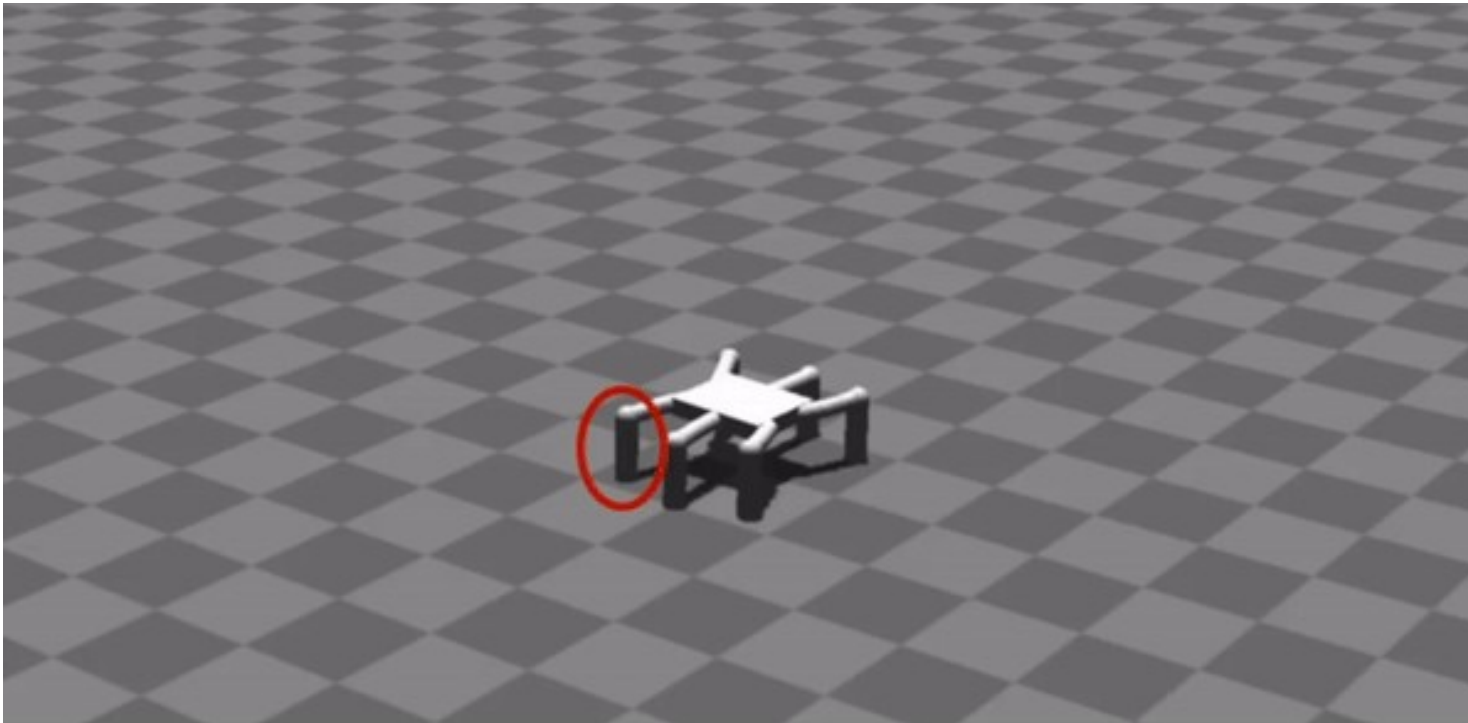
"Tacking" involves steering a vessel into the wind and then angling outward again so that progress in a zig-zag, roughly in the desired direction, can still be made.

Under unfavourable weather conditions, the self-flying balloons had learned to tack all by themselves. The fact they had done this, unprompted, surprised everyone, not least the researchers working on the project.



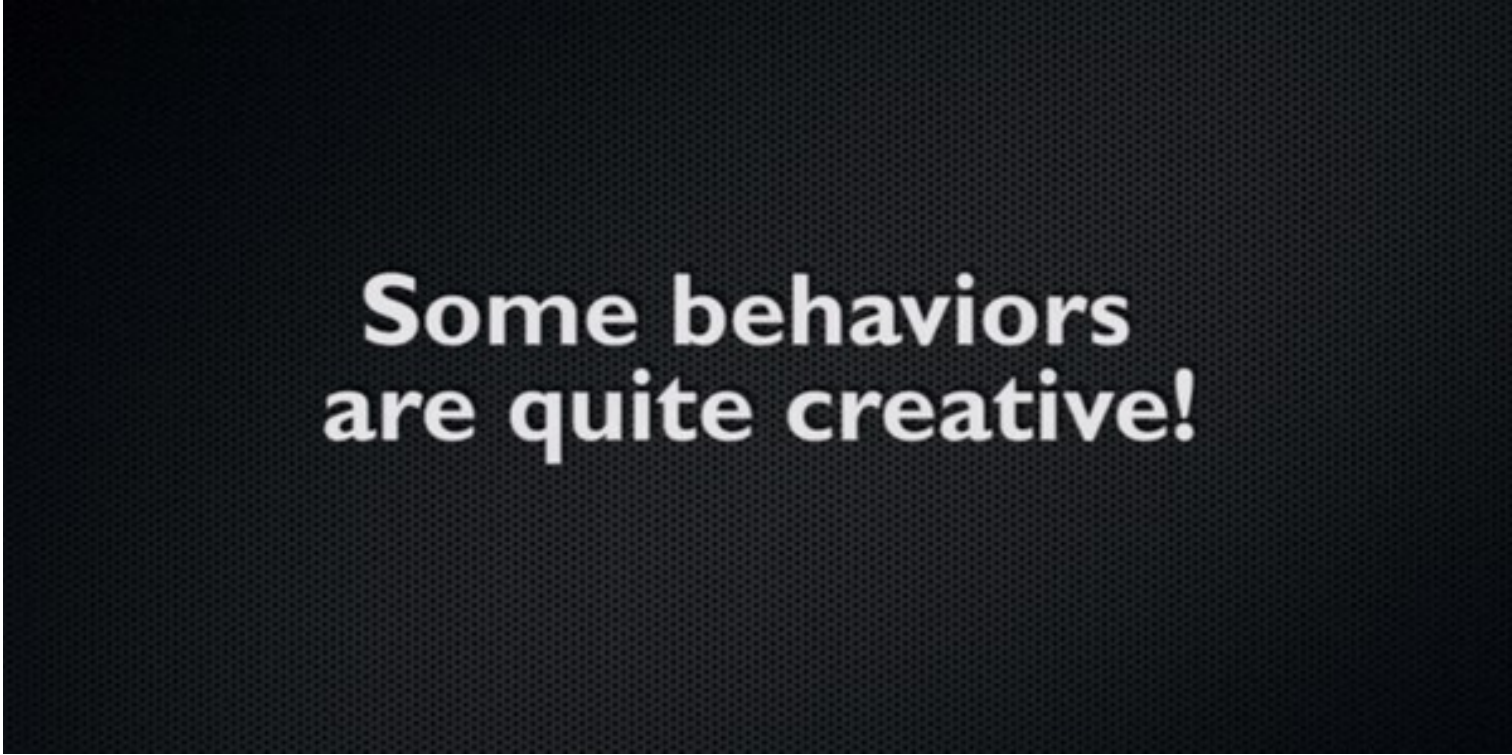
The Surprising Creativity of Digital Evolution: A Collection of Anecdotes from the Evolutionary Computation and Artificial Life Research Communities

Joel Lehman^{1†}, Jeff Clune^{1, 2†}, Dusan Misevic^{3†}, Christoph Adami⁴, Lee Altenberg⁵, Julie Beaulieu⁶, Peter



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**Some behaviors
are quite creative!**

BTW...Despite All the Learning Power and Training,
System Could fail...



“panda”

57.7% confidence

+ .007 ×



noise

=



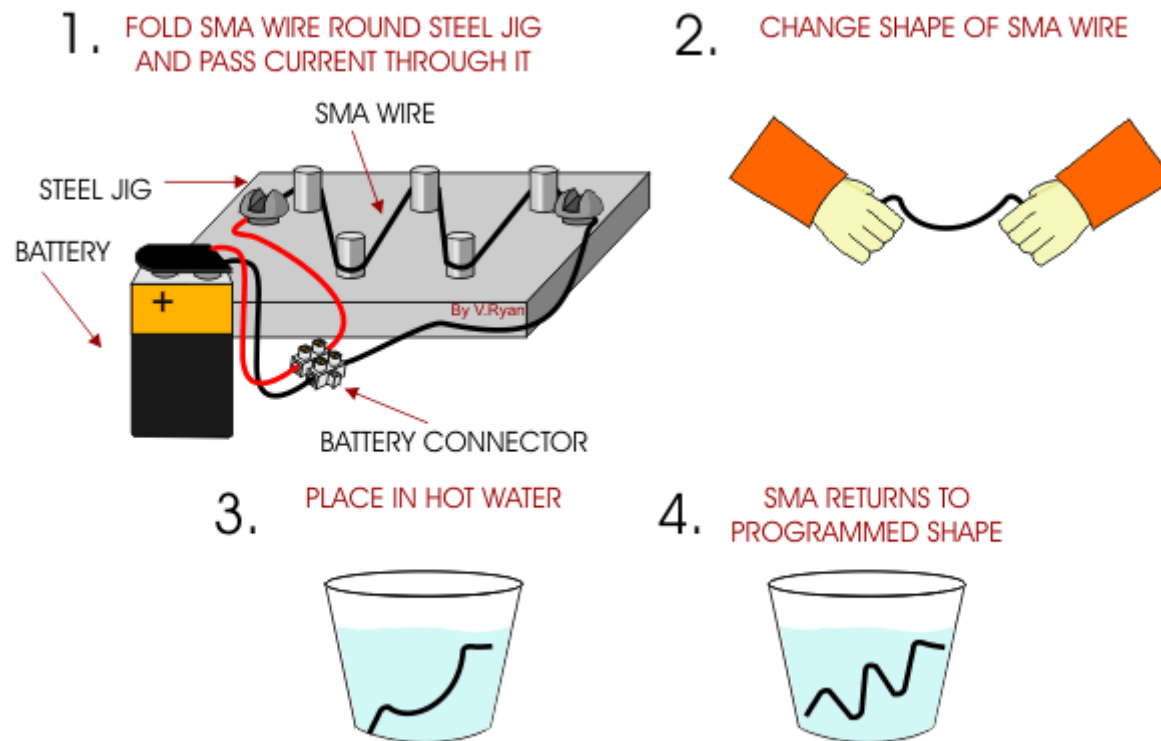
“gibbon”

99.3% confidence

The Magic of Learning!

- How do you think machines learn?
 - Mostly *algorithmically*!
 - Is there any other way?

The Magic of Learning! (In Smart Materials...)



- Trained using some physical property.
- Returns to trained state under "right" environment.

The Magic of Learning! (In Smart Materials...)



- Trained using some physical property.
- Returns to trained state under “right” environment.

Questions?? Thoughts??

